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Moving beyond convergence in the pheromone system of the moth

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Introduction

Male moths can sense and locate conspecific females releasing small amounts of pheromone from more than a mile away [1]. Integral to this behavior is the extraordinary sensitivity of the male moths olfactory apparatus to pheromone molecules. This apparatus involves the transduction of molecular binding events in large populations of olfactory receptor neurons (ORNs) and their convergent projections onto relatively small numbers of neurons in the macro glomerular complex (MGC). Schneider calculated a behavioral threshold of the pheromone system of 200 molecular binding events at the antennae [1]. Recently Angioy et al. have reported that fluctuations of the male moths cardiac rhythm were elicited with a calculated 6 molecular events at the antennae [2]. While it has been demonstrated that ORN are capable of producing spikes after only a single molecular binding event the overall sensitivity of the systems is limited by noise in the

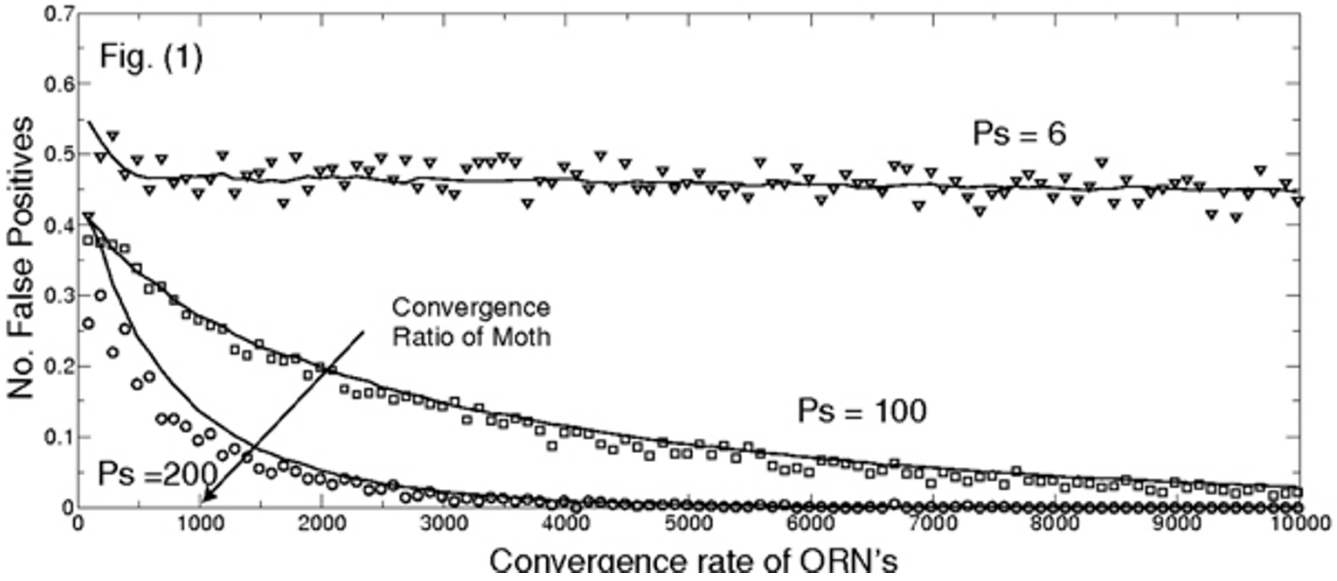

Figure 1

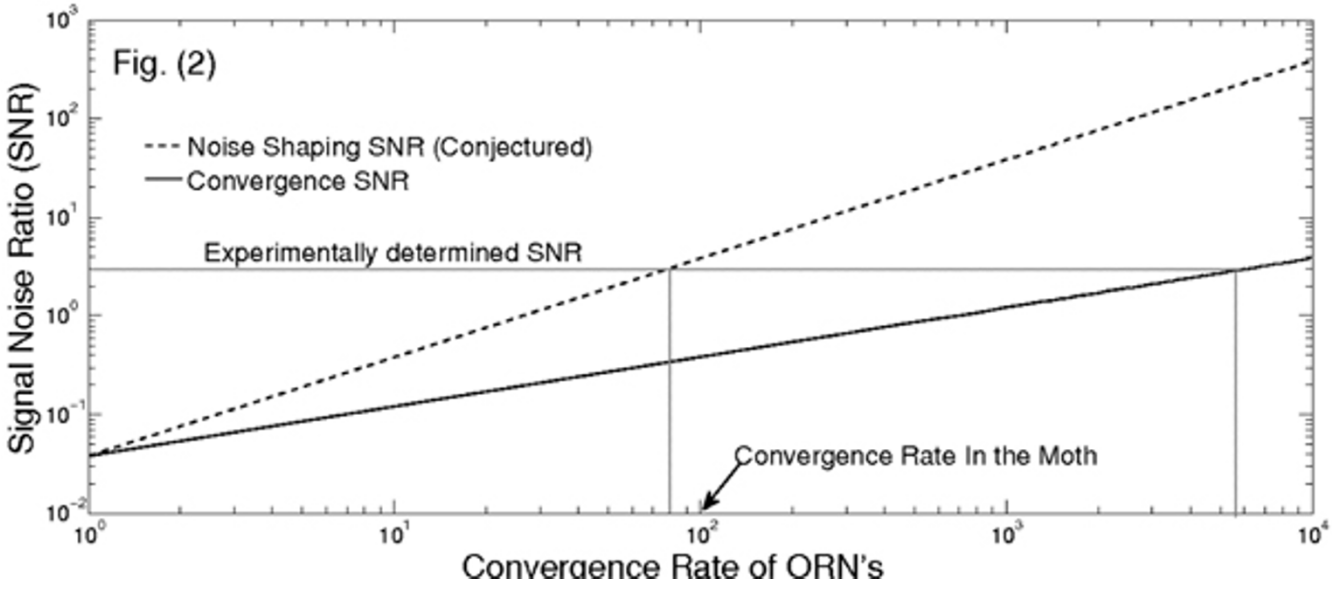

Figure 2

ORNs. The statistical properties of the convergence pathways from ORNs to the neurons of the MGC have been suggested as a possible solution to this problem [3]. In this work we analyze a statistical model in order to investigate whether the signal to noise (SNR) enhancement properties of convergent projections are sufficient to explain the sensitivity of moths to low pheromone concentrations.

Model and conclusion

The model comprises of an ensemble of N binary elements (representing the 17000 ORNs in the moth) that are activated with probability P_n (1600/17000) and P_n+P_s ((1600+P_s)/17000) in presence or absence of pheromone, respectively. The output of these units converges on a McCulloch and Pitts neuron. Figure 1 shows the number of false positives (positive behavioral response in the absence of pheromone) against the convergence rate for three different P_s values. Simulated (symbols) and analytical results assuming Poisson statistics (lines) are shown. The data demonstrates that for a biologically plausible convergence rate of 1000 the number of false positives exceeds that found in experiments (zero in 30 subjects) [1]. The solid line in Figure 2 shows the SNR against the convergence rate. It shows that SNR calculated in moth cannot be explained by simple convergence phenomena for a convergence rate of 1000. In conclusion, the statistical properties of convergence may not be enough to explain the sensitivity of the moth pheromone system. The dashed line in Figure 2 gives the SNR for noise shaping [4] which has been put forward as a candidate mechanism to explain the olfactory sensitivity of the moth.

Acknowledgements

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